U. S. NAVAL SCHOOL OF AVIATION MEDICINE

Special Report

# NOISE ATTENUATION CHARACTERISTICS OF THE GENTEX-RCA X-1 AND THE RCA X-2 PERSONNEL NOISE PROTECTIVE DEVICES

Special Report No. 18 of TED PEN AE 1403

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Report by

Gilbert C. Tolhurst



Naval Aviation Medical Center

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Approved by

Captain Ashton Graybiel, MC USN
Director of Research

Released by

Captain Langdon C. Newman, MC USN
Commanding Officer

30 January 1959

## SUMMARY PAGE

### THE PROBLEM

An evaluation was made as to the tone, noise, and speech threshold attenuation characteristics of the Gentex RCA X-1 and the RCA X-2 personnel noise protective devices, each tested with a liquid ear cushion and a foam rubber ear cushion. Two general types of measures were obtained: 1) physical measures taken from the output of a miniature condenser microphone serving as an artificial ear mounted within a plaster manikin head; and 2) listener-observer judgments of threshold shift, normal listening versus device over the ears, to the various stimuli presented ambiently to 10 individuals. The judgments included responses to: a) pulsed pure tone at eight discrete frequencies, b) pulsed wide-band and octave-bands of noise, and c) Spondee words.

### FINDINGS

Both the physical and the subjective relative attenuation measures show that the RCA X-2, employing both ear cushions affords as much attenuation as, or more than, the V-51R. The Gentex RCA X-1 was not so efficient as the V-51R at the lower frequencies or bands of noise but was for the higher frequency range.



## ACKNOWLEDGEMENT

Mr. Robert T. Camp, Jr. acted as principal experimenter and provided technical assistance.

## INTRODUCTION

In order to comply with a request of the Bureau of Aeronautics (Aer-AE-522/38 letter, dated 7 August 1958) an evaluation of the sound attenuation characteristics was made of two "Flite Deck Helmets," Gentex-RCA type X-1 and RCA type X-2, universal fit. Since the cushions providing the circum-auricle seal to the head were interchangeable, each helmet was evaluated with both cushions. The summary of the findings was to be designated Report No. 18 of TED PEN AE-1403.

Two general sets of measures were obtained on each helmet with the "sealing pads" interchanged resulting in four sets of measures, two for each helmet.

## PROCEDURE

The two sets of data obtained on the X-1 and X-2, both types of ear cushions were: 1) physical measures employing an artificial ear, and 2) three sets of judgmental responses to three different series of sound stimuli. These procedures have been previously reported in TED PEN AE 1403, reports numbered 6 through 17.

### PHYSICAL MEASURES

The physical measures were relative attenuation values obtained from the output of an Altec 150-BR condenser microphone used as an artificial ear appropriately positioned within a plaster manikin head. The specific techniques and equipment have been fully described previously in reports TED PEN AE-1403.1, .3, .4, .6 and .9. The relative attenuation values obtained were the differences in db sound pressure level (re 0.0002 dyne/cm$^2$ ) between the microphone output when the manikin head did not have the specific protective helmet in place versus the microphone output when the device was positioned on the manikin head.

### SUBJECTIVE MEASURES

The subjective measures comprise the responses of 10 individuals (male) with normal, or better than normal hearing acuity. The listening tasks were threshold responses to each of three sets of sound stimuli and have been described earlier in Reports 1403.1, .6 and .9. Each of the three listening tasks was a threshold judgment with the protective device covering the ears compared to a basic threshold judgment with the ears unprotected.

The responses required from the listeners were binaural threshold judgments as the sound stimuli were ambiently introduced into the sound-proofed, sound-treated testing room. The three criterion measures were: a) a pulsed pure tone threshold shift in db (three experimental sessions per individual for each helmet, both ear cushions, at eight discrete frequencies); b) pulsed wide-band and octave-band noise threshold shifts (one relative attenuation value per individual per noise band per helmet condition); and c) Spondee word threshold shift judgments (one observation per individual per helmet per cushion).

The proposed American Standards Association standard procedures for real-ear evaluation of protective devices were employed in obtaining the present pulsed pure tone threshold shift judgments. Each pure tone relative attenuation value, then, is the mean threshold shift of three observations of each of the ten listeners obtained at three different experimental sessions. Hence, each of the values reported is the mean of 30 judgments.

All of the factors of the experimental testing situation conform to the proposed ASA standard, for example, the noise floor of the testing room, the "fitting" of the protective device, listener-observer positioning, et cetera.

## RESULTS

### PHYSICAL MEASURES

The sound pressure output of the miniature condenser microphone, in place as an artificial ear within the plaster manikin head, was automatically plotted on a graphic device (Bruel and Kjaer Level Recorder, Model 2301). This yielded a frequency-intensity response characteristic plot of the system (microphone and plaster head) without a protective device in position, and then another curve was superimposed on the first with the specific device in place over the artificial auditory meatus. The decibel differences between the two curves yielded the sound pressure level attenuation values. The sound pressure level ambient in the sound room was set at 128 db at 2500 cps as the calibration reference value. The artificial ear relative attenuation values are given in Table I.

The artificial ear-manikin head tests yielded relative attenuation values for both helmets not quite so high as the V-51R at frequencies above 1000 cps but were greater below that frequency. The four permutations of helmets and ear cushions could be ranked as to their relative attenuation efficiency in the following order: a) RCA X-2, liquid cushion; b) X-2, foam rubber cushion; c) Gentex RCA X-1, liquid cushion; and d) X-1, foam cushion. The above ranking is not a frequency by frequency comparison but rather a generalized one. For example, there are reversals at 250, 1000, and 4000 cps between the X-1 (liquid cushion) and the X-2 (foam cushion). However, values obtained from the graphic record which differ by only 1 db are probably not different due to the error of reading the measurements.

Sound pressure level relative attenuation values were also obtained from the output of the artificial ear under the conditions of the protective helmet off versus the helmet in place when the noise field was 120 db of three continuous noise types introduced ambiently into the sound room. Table II lists these relative values in addition to similar values obtained earlier on the V-51R.

The relative attenuation values in Table II, as they relate to the four helmet conditions, could be ranked in the same order as they were for the discrete frequency data above. (See Table I.) Each of the helmets utilizing both ear cushions gave higher attenuation values for ASA white noise than did the V-51R.

Table I

Discrete Frequency Relative Attenuation Values in db Obtained From an Artificial Ear Within a Plaster Dummy Head. Sound Pressure Reference Level, 128 db at 2500 cps. Similar Values Previously Obtained on The V-51R are Also Given

| Frequency | Relative Attenuation (db) Gentex-RCA X-1 Foam Cushion | Gentex-RCA X-1 Liquid Cushion | RCA X-2 Foam Cushion | RCA X-2 Liquid Cushion | V-51R |
|---|---|---|---|---|---|
| 75 cps | 12 | 15 | 28 | 31 | |
| 125 | 23 | 21 | 22 | 28 | 11 |
| 250 | 29 | 34 | 33 | 40 | 25 |
| 500 | 25 | 32 | 31 | 36 | 19 |
| 1 kcs | 43 | 38 | 36 | 34 | 42 |
| 2 | 32 | 37 | 40 | 40 | 42 |
| 4 | 36 | 38 | 31 | 42 | 48 |
| 8 | 43 | 30 | 40 | 38 | 45 |
| 10 | 37 | 37 | 37 | 42 | |

Table II

Relative Attenuation Values in db Obtained From the Artificial Ear-Manikin Head. Ambient Sound Pressure Level was 120 db of ASA White Noise, Harvard Generator Noise (Spectrum No. 1) and Recorded JRB Noise. Values Previously Obtained on the V-51R are Also Given

| Noise Type | Relative Attenuation (db) Gentex-RCA X-1 Foam Cushion | Gentex-RCA X-1 Liquid Cushion | RCA X-2 Foam Cushion | RCA X-2 Liquid Cushion | V-51R |
|---|---|---|---|---|---|
| ASA White | 27 | 32 | 35 | 36 | 20 |
| Harvard (Spect. 1) | 15 | 19 | 29 | 29 | 18 |
| Recorded JRB | 21 | 24 | 31 | 32 | 18 |

SUBJECTIVE MEASURES

a) Pulsed Pure Tone Threshold Shift

Audiograms (Bekesy Audiometer) were obtained on the ten members of the listening panel. All had normal or better hearing. Each member contributed threshold judgments at three different sessions per helmet for both ear cushion types separated in time by a minimum of six hours. The averaged pulsed pure tone threshold shift values were calculated for each of the eight discrete frequencies presented as stimuli, totalling thirty judgments per frequency. Table III lists the mean relative pure tone threshold shift judgment values and the associated standard deviations for the X-1 (both foam rubber and the liquid filled ear cushion) and the X-2 helmet (both cushions) along with the values obtained previously on the V-51R ear warden. Mean threshold shift curves for each helmet are plotted in Figures 1 and 2. Standard deviations are also plotted for the protective helmets, not for the V-51R.

Table III

Mean Relative Pulsed Pure Tone Threshold Shifts and Standard Deviations in db for the Gentex-RCA X-1 and RCA X-2 (N = 10, Three Judgmental Sessions Per Observer) Plus the Same Values on The Two Devices With The Cushion Seals Interchanged (N = An Additional 10 Observers, Three Sessions Per Individual). Similar Threshold Shift Values Obtained From the V-51R are also Given

| | X-1 | | | | X-2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Foam Cushion | | Liquid Cushion | | Foam Cushion | | Liquid Cushion | | V-51R | |
| Frequency | M. | S.D. | M. | S.D. | M. | S.D. | M. | S.D. | M. | S.D. |
| 75 cps | 8 | 4.85 | 10 | 3.84 | 15 | 3.94 | 15 | 5.59 | | |
| 125 | 8 | 3.63 | 10 | 2.73 | 18 | 2.93 | 19 | 3.67 | 14 | 6.7 |
| 250 | 5 | 3.60 | 9 | 3.50 | 14 | 3.81 | 19 | 4.66 | 15 | 5.8 |
| 500 | 14 | 4.58 | 18 | 3.69 | 28 | 3.35 | 30 | 4.74 | 16 | 6.5 |
| 1000 | 27 | 5.06 | 27 | 3.69 | 33 | 4.81 | 35 | 4.75 | 22 | 9.0 |
| 2000 | 37 | 5.85 | 31 | 6.34 | 35 | 4.78 | 37 | 5.85 | 26 | 10.3 |
| 4000 | 31 | 7.64 | 34 | 6.18 | 38 | 5.20 | 36 | 6.26 | 30 | 7.5 |
| 8000 | 27 | 6.45 | 29 | 5.12 | 36 | 6.80 | 34 | 6.07 | 26 | 9.3 |

The attenuation effectiveness of the two protective helmets, two ear cushions per helmet, could be ranked as to their subjective threshold shifts as follows: 1) X-2 with the liquid cushions, 2) X-2 with the foam rubber cushions, 3) X-1 with the liquid cushion, and 4) X-1 with the foam rubber cushion. The subjective rankings agree with those of the physical measures obtained from the plaster manikin head.

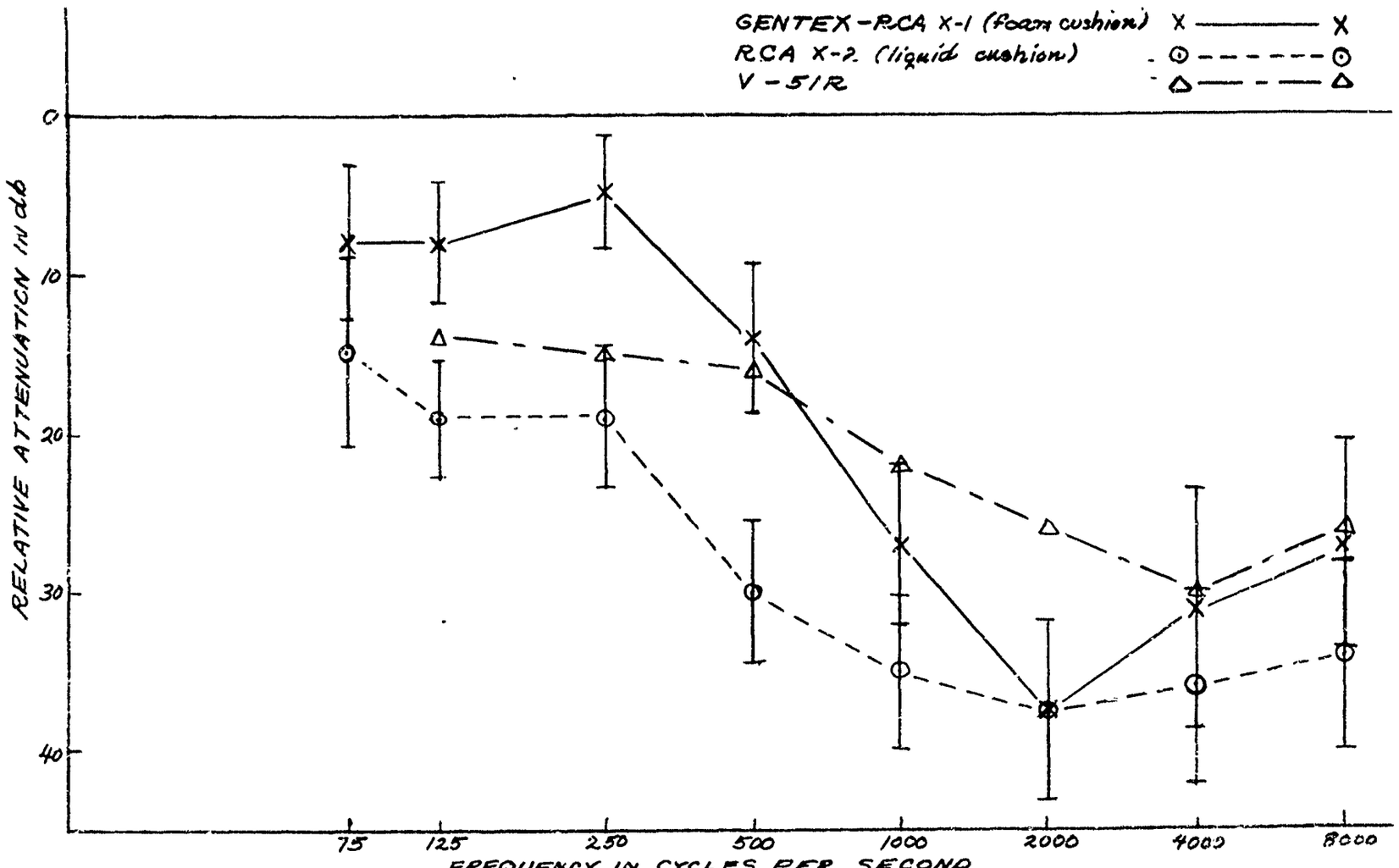


FIGURE 1

AVERAGE PULSED PURE TONE THRESHOLD SHIFTS (IN db) & STANDARD DEVIATIONS FOR GENTEX-RCA X-1 (FOAM CUSHION) AND RCA X-2 (LIQUID FILLED CUSHION). MEAN VALUES FOR THE V-51R EAR WARDEN ARE COMPARED. 30 JUDGMENTS PER POINT

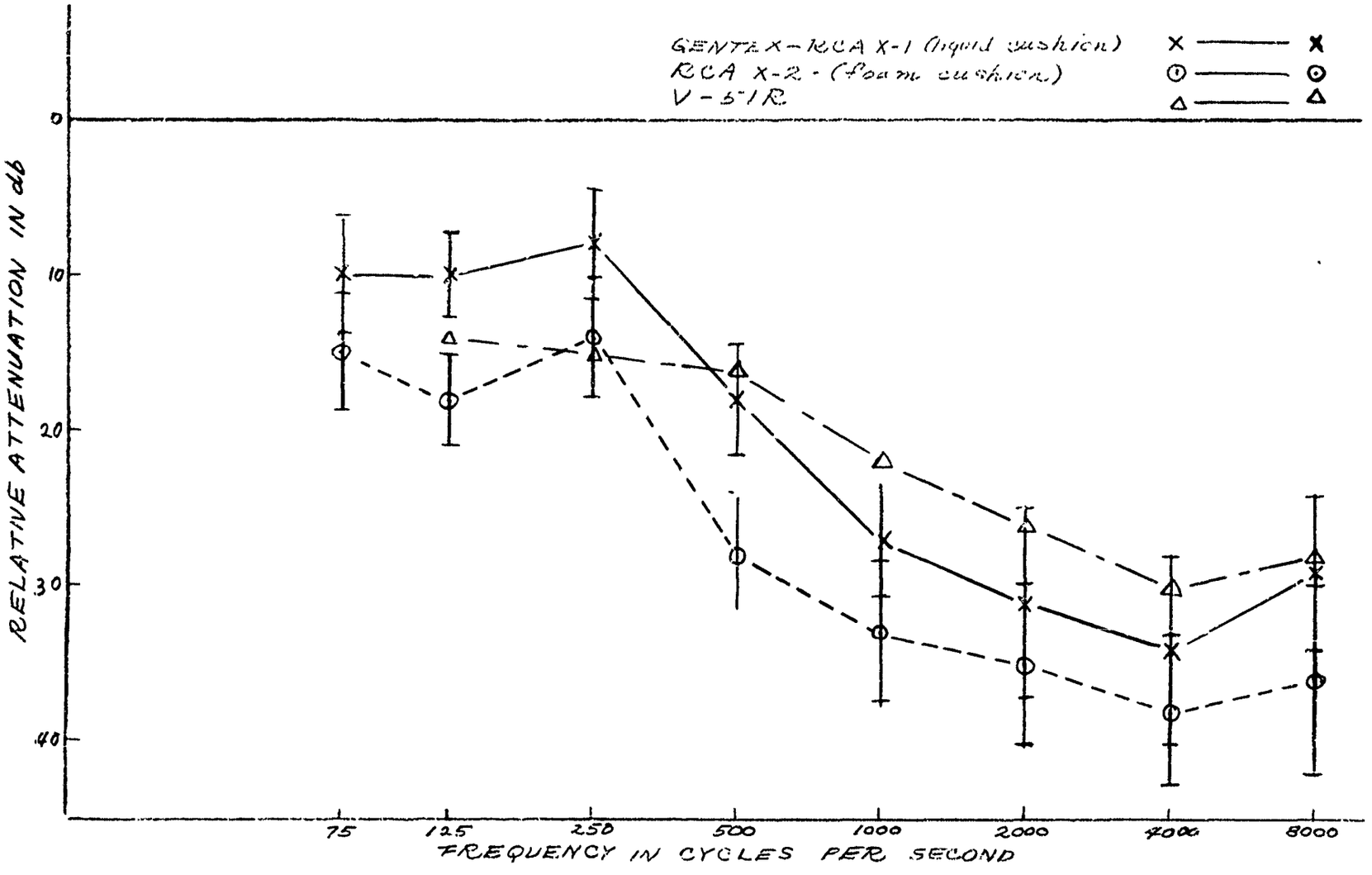


FIGURE 2

AVERAGE PULSED PURE TONE THRESHOLD SHIFTS (IN db) & STANDARD DEVIATIONS FOR GENTEX-RCA X-1 (LIQUID CUSHION) AND RCA X-2 (FOAM EAR CUSHION). MEAN VALUES FOR THE V-51R EAR WARDEN ARE COMPARED. 30 JUDGMENTS PER POINT

An examination of Table III and Figures 1 and 2 indicates that the RCA X-2 with either ear cushion affords greater attenuation than the V-51R. This is particularly true for the critical frequencies of 250 cps and below. Undoubtedly this is due to the greater volume of the X-2 which appears to be the most efficient when coupled to the head by the liquid filled ear cushion. The Gentex-RCA X-1 did not demonstrate higher relative attenuation values than the V-51R at frequencies below 500 cps but did yield greater attenuation above that frequency region.

b) Pulsed Wide Band and Octave Bands of Noise Threshold Shifts

The decibel means listed in Table IV are the averaged relative threshold shift values derived from the judgments of each of the 10-member listener panel. The stimuli consisted of pulsed wide-band noise and octave-bands of noise filtered from a flat white noise source. A graph of these means and standard deviations is found both in Figures 3 and 4. Mean attenuation values of the V-51R previously obtained from the above stimuli are also found in Table IV and Figures 3 and 4.

Table IV

Mean Relative Pulsed Wide-Band and Octave-Band Noise Threshold Shifts And Standard Deviations in db For The Gentex-RCA X-1 and RCA X-2 (N = 10) Plus the Same Measures on the Two Devices With the Cushion Seals Interchanged (N = 10 Additional Observers). Values Previously Obtained on the V-51R are Also Given

| | X-1 | | | | X-2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Foam Cushion | | Liquid Cushion | | Foam Cushion | | Liquid Cushion | | V-51R | |
| Noise Bands | M | S.D. | M | S.D. | M | S.D. | M | S.D. | M | S.D. |
| 20-10,000 cps | 19 | 3.46 | 22 | 3.44 | 28 | 2.87 | 28 | 2.63 | 22 | 4.3 |
| 20-75 | 8 | 5.95 | 10 | 1.75 | 17 | 1.97 | 18 | 0.50 | | |
| 75-150 | 10 | 4.80 | 12 | 3.21 | 18 | 3.23 | 21 | 2.65 | 16 | 4.0 |
| 150-300 | 8 | 2.89 | 11 | 2.20 | 20 | 5.26 | 21 | 4.76 | 17 | 2.3 |
| 300-600 | 11 | 2.94 | 16 | 3.39 | 27 | 5.74 | 27 | 3.15 | 18 | 4.4 |
| 600-1200 | 22 | 3.86 | 25 | 3.69 | 32 | 2.74 | 36 | 3.81 | 18 | 3.0 |
| 1200-2400 | 28 | 3.20 | 32 | 1.34 | 33 | 3.01 | 33 | 3.45 | 25 | 4.0 |
| 2400-4800 | 25 | 4.47 | 31 | 4.61 | 31 | 3.62 | 30 | 4.70 | 29 | 4.2 |
| 4800-10,000 | 29 | 3.12 | 29 | 3.13 | 32 | 5.66 | 32 | 3.72 | 29 | 4.9 |

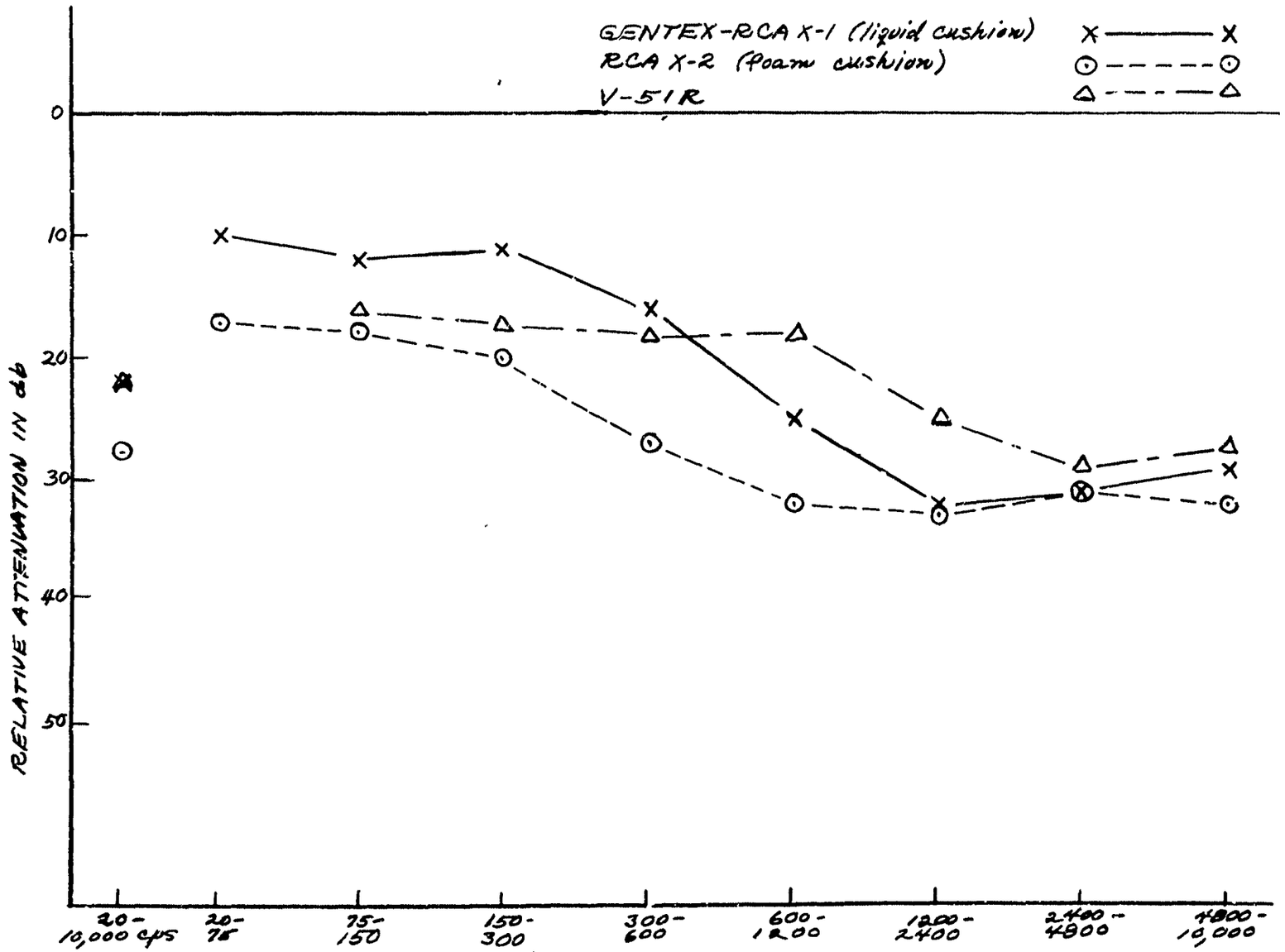


FIGURE 4

MEAN BANDS-OF-NOISETHRESHOLD SHIFTS & STANDARD DEVIATIONS FOR GENTEX-RCA X-1 (LIQUID CUSHION) AND RCA X-2 (FOAM CUSHION). SIMILAR VALUES FOR THE V-51R ARE ALSO SHOWN. 10 JUDGMENTS PER POINT

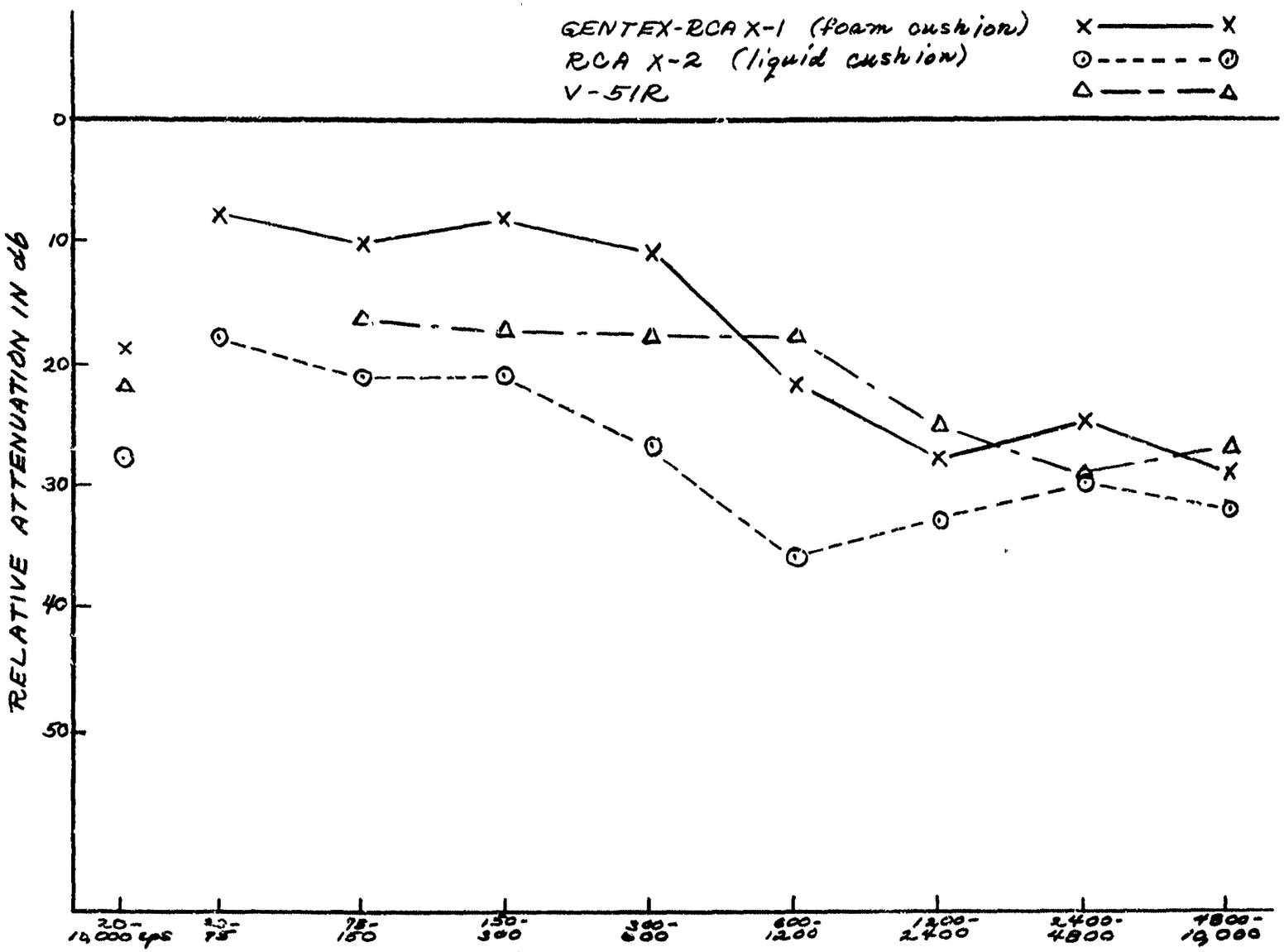


FIGURE 3

MEAN BANDS-OF-NOISE THRESHOLD SHIFTS & STANDARD DEVIATIONS FOR GENTEX-RCA X-1 (FOAM CUSHION) AND RCA X-2 (LIQUID CUSHION). SIMILAR VALUES FOR THE V-51R ARE ALSO SHOWN. 10 JUDGMENTS PER POINT

The threshold shift relative attenuation values indicate that the helmets (and ear cushion permutations) could be ranked in the same manner as found for the pure tone data, i.e., Part a. The attenuation for wide-band noise of the X-2 (both cushions) exceeded the values found for the V-51R and the X-1. The X-1 with the liquid cushion yielded attenuation values to wide-band noise equal to those of the V-51R but was somewhat poorer than the same cup with the foam rubber cushion. The subjective threshold shift values, when ranked, yielded comparable relative attenuation values to those found when the artificial ear-manikin head was subjected to 120 db of ASA white noise.

c) Spondee Word Reception Threshold Shift

The criterion value of Spondee word reception threshold has been defined as the level at which 50 per cent correct word reception was achieved. The mean threshold shifts afforded by the protective device, i.e., device on versus device off, are listed in Table V along with standard deviation values for the 10-listener-observer panel. Comparable values previously determined for the V-51R are also given. Figure 5 is a bar graph of the data found in the Table.

Table V

Mean Relative Threshold Shift for Spondee Words and Standard Deviations for the Gentex-RCA X-1 and RCA X-2 (N = 10) Plus the Same Measures on the Two Devices With the Cushion Seals Interchanged (N = 10 Additional Observers). Previously Obtained Values for the V-51R Are Also Given

| Device | Threshold Shift | |
|---|---|---|
| | M | S.D. |
| Gentex-RCA X-1 (foam cushion) | 17 | 6.48 |
| Gentex-RCA X-1 (liquid cushion) | 24 | 8.87 |
| RCA X-2 (foam cushion) | 27 | 9.94 |
| RCA X-2 (liquid cushion) | 27 | 9.30 |
| V-51R | 18 | 3.50 |

The indications from the Spondee word threshold shift data are that the RCA X-2 with either ear cushion gave greater relative attenuation than did the Gentex-RCA X-1 or the V-51R. An observation generalized from the present data is that the Spondee word threshold shift is within 1 db, each device and ear cushion combination, of the relative threshold shift values for the wide-band noise. The present observation is somewhat different from those found in Special Reports TED PEN AE-1403.12 and .17 in which the Spondee word threshold shift values were closer to the mean of the 300-600, 600-1200 and 1200-4800 cps octave bands of noise. In the present instance the mean values of the three noise bands would be lower (show greater relative attenuation) than those found for Spondee words.

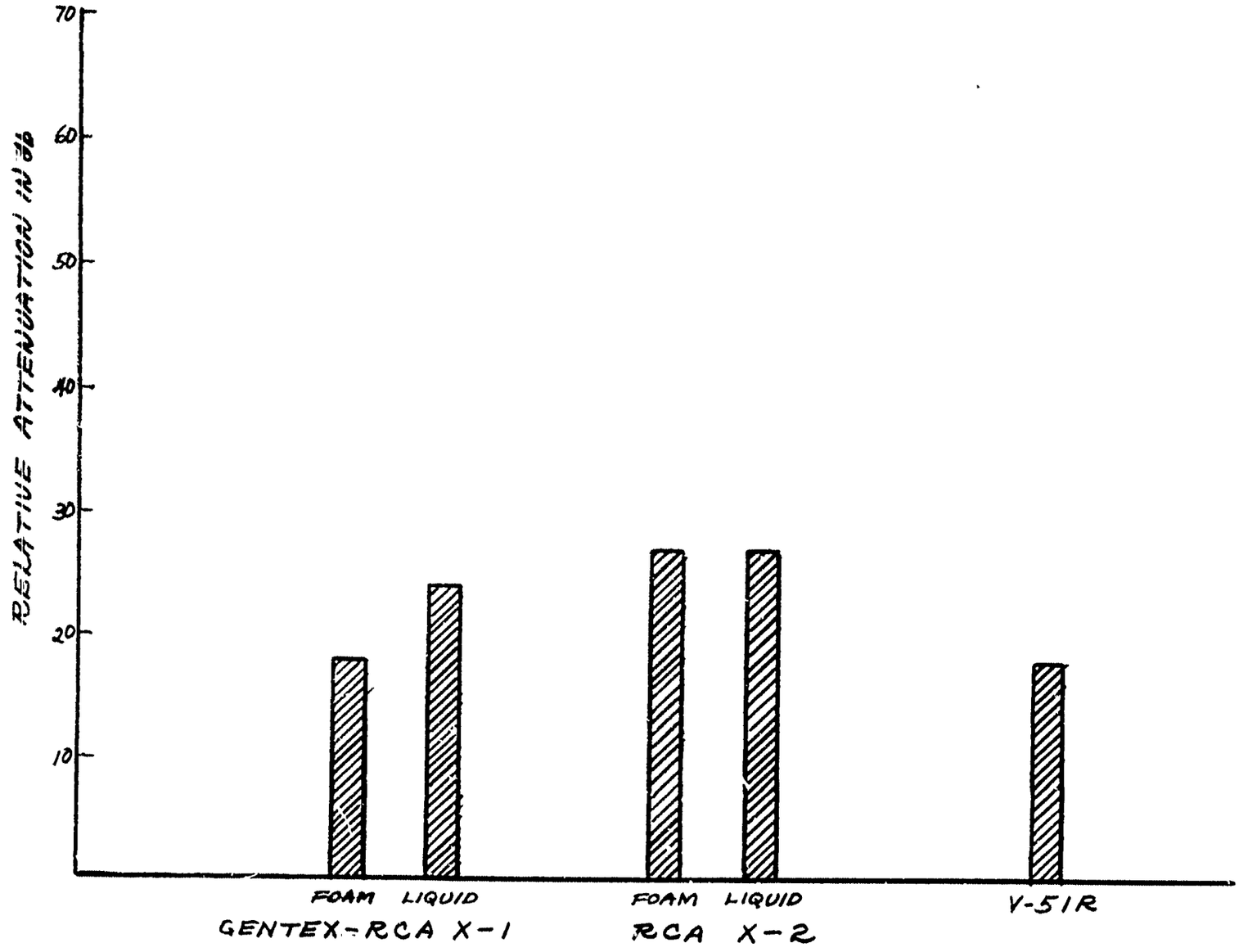


FIGURE 5

SPONDEE WORD THRESHOLD SHIFTS FOR THE GENTEX-RCA X-1 (BOTH EAR CUSHIONS) AND RCA X-2 (BOTH CUSHIONS). THE MEAN OF SIMILAR MEASURES FOR THE V-51R ARE SHOWN.

## NON-EXPERIMENTAL CONSIDERATIONS

1. The woven cloth material of both helmets seemed to give a snug, yet comfortable, support for the ear cups.

2. The liquid ear cushion was reported to be more comfortable under the laboratory testing conditions than the foam rubber cushion.

3. The elastic band providing tension on the X-1 helmet had to be checked for proper position each time the helmet was worn. The guide projections of the X-2 seemed adequate to hold the elastic strap and requiring little, if any, readjusting.

It is suggested that the elastic straps that provide increased pressure to the ear cups, hence a better seal around the auricle, should be tested for possible deterioration if lubricants or aircraft fuel come in contact with them.

4. An individual wearing the RCA X-2 would need at least 12 inches clearance for his head when wearing this helmet. The average distance (sagittal axis) between the extremities of the two ear cups was 11.5 inches. Only an evaluation under operational conditions would determine if the width of the helmet is excessive.

# CONCLUSIONS

## PHYSICAL DATA

The relative attenuation measures obtained from the artificial ear-manikin head gave higher values for both helmets (both ear cushions) than did the V-51R at frequencies below 500 cps, but not above. It was possible to rank the effectiveness of the devices: 1) X-2, liquid cushion; 2) X-2, foam cushion; 3) X-1 liquid cushion; and 4) X-1 foam cushion.

## LISTENER THRESHOLD SHIFT DATA

a) The pulsed pure tone relative attenuation values could be ranked as follows: 1) X-2, liquid ear cushion; 2) X-2, foam cushion; 3) X-1, liquid cushion; and 4) X-1 foam cushions. Greater attenuation was found for the X-2 than for the V-51R and also for the X-1 for frequencies above 500 cps.

b) The same ranking could be given the relative attenuation results from noise stimuli as for the pure tone data. The cross-over in which the X-1 shows greater attenuation than the V-51R is between the 300-600 cps and 600-1200 cps frequency region.

c) Both ear cushions when associated with the X-2 helmet yielded greater attenuation for Spondee words than the V-51R. This was also true for the X-1 with the liquid ear cushion but did not hold true when the seal was the foam rubber ear cushion.